An Apparatus for Mechanically Calculating Star Corrections.

By W. E. Cooke.

(*Communicated by Professor H. H. Turner.*)

This machine, the principal part of which is shown in plan in the accompanying diagram (see plate 5), is mounted on a deal table with a cover, the top of which can be used as a drawing-board.

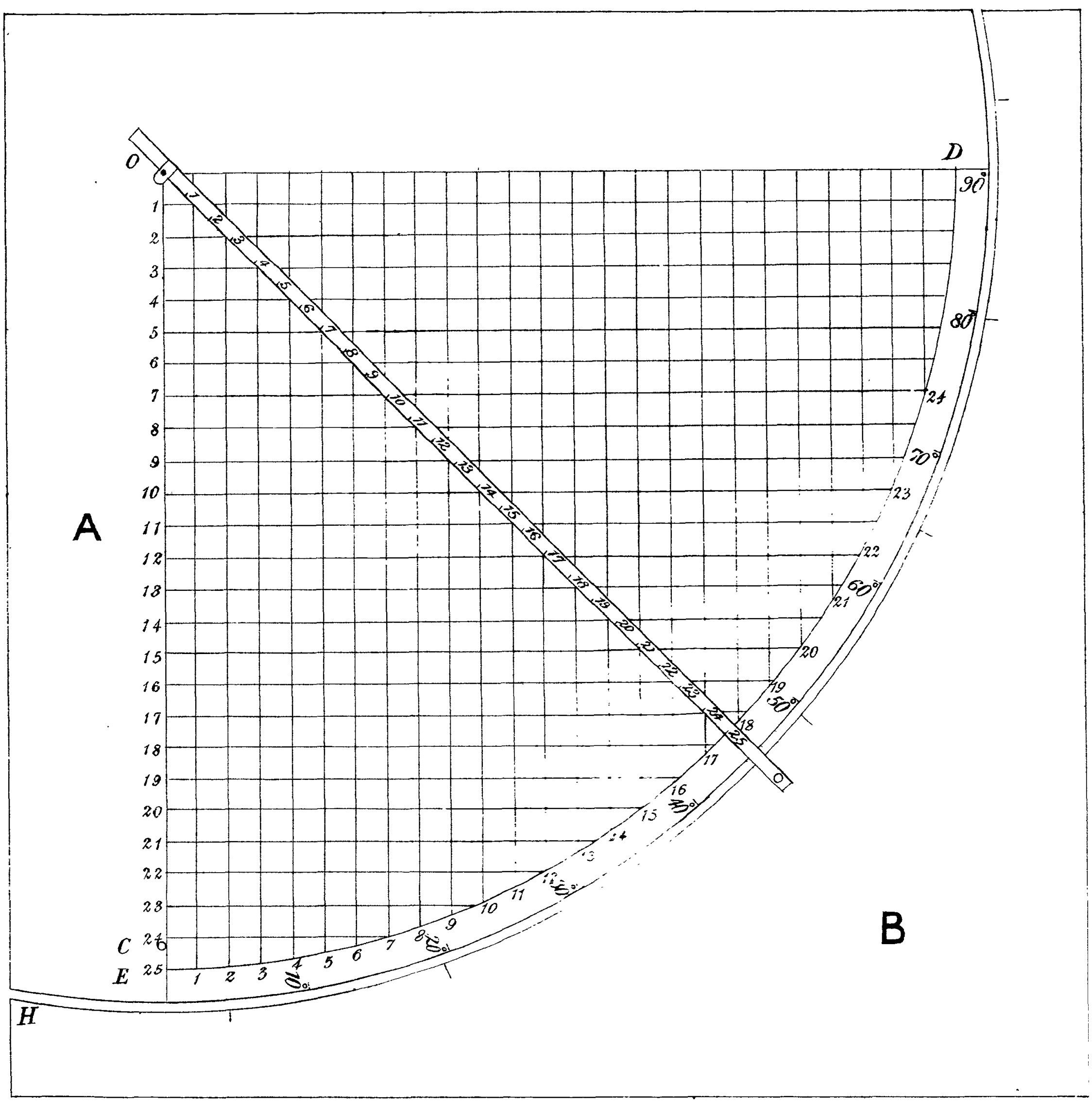
It consists essentially of a square sheet of zinc, divided into two portions, A and B, by means of a circular cut. B is fixed securely to the table top, and A is pivoted at O, a substantial spindle ($\frac{3}{8}$ inch thick) being screwed to the table, passing through a metal sheath in A, and projecting slightly above it. A flat metal straightedge, or ruler, 28 inches long, having a small metal projection near one end, through which a $\frac{3}{8}$-inch circular hole is drilled, with its centre exactly in line with the edge of the ruler, is pivoted on that portion of the spindle which projects above A. On the under side of A, at the point marked C, clamping and tangent screws are fixed, passing through a slotted aperture of 20° in the table top.

Thus both A and the ruler can be turned, independently of each other, on the spindle O, and A can be clamped in any desired position.

On A the quadrant ODE is drawn. Each line or radius OD and OE is divided into tenths of an inch, and perpendiculars drawn through each point, thus reticulating the quadrant into 0·1 inch squares. Every tenth division is marked by a thick black line, corresponding to each second of arc. (These only are shown in the accompanying diagram figured 0 to 25, commencing from the centre 0.) The half seconds, or every alternate fifth division, are drawn in red, and a thin black line marks the intermediate divisions, or tenths of seconds. The ruler, pivoted at 0, is similarly divided 0–25.

The edge of the quadrant is divided into degrees, and every tenth minute of arc, starting at E, and every minute can be easily estimated. The rim of B is graduated into hours and minutes, starting at H and extending for 7^h. The minutes are figured, but the hours are *not*.

For any given night's work we have a set of stars extending over 2 or 3 hours in R.A. Take any one of these hours, multiply by 15 to reduce to degrees, and add to G (from the *Nautical Almanac*). This gives $(G+\alpha)$ corresponding to some whole hour of α. Let us take a simple case first. Suppose this value of $(G+\alpha)$ is less than 90°. Turn A on its pivot until $(G+\alpha)$ on the rim of A corresponds with some (unfigured) whole hour on the rim of B and then clamp. Then with a pencil figure this par-



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ticular hour according to the above value of a. [As a matter of practice it is unnecessary to clamp. or to actually write in this value of a, for the stars to be reduced generally run straight forward in R.A.]

To obtain g sin $(G+a)$ and g cos $(G+a)$ for any value of a, move the ruler until its edge corresponds with the given value of a as read on B. The $\angle$ EOa will then be $(G+a)$, and the value of g on the ruler's edge will give g sin $(G+a)$ and g cos $(G+a)$ as read off on the reticulated quadrant. When these quantities have been obtained for each star, take out similarly the values of h sin $(H+a)$ and h cos $(H+a)$. Then set the ruler to the dec. of any star, and without moving it read off $[g \sin (G+a)] \sin \delta$, $i \cos \delta$, and $[h \cos (H+a)] \sin \delta$. Also, if it come within the limits of the machine, multiply the sum of g sin $(G+a)$ sin δ and h sin $(H+a)$ by sec. δ. This is done by reversing the above operation—*i.e.* take the value of this sum along OE and find where the corresponding perpendicular cuts the ruler. Of course, if either this sum, or the value of δ be large, the machine will not be able to multiply by the sec. δ.

We took just now the simple case where $(G+a)$ or $(H+a)$ is less than 90°. If it be > 90°, subtract either 90°, 180°, or 270°, as required, reading sin. for cos. where necessary, and prefixing the appropriate sign.

If, after setting A for some definite value of $(G+a)$ and running the ruler round the quadrant for successive stars, we reach D, we must bring the ruler back again to E, and read cos. for sin., and *vice versa.*

As to a practical test of accuracy and speed, we have only just completed the instrument at the Adelaide Observatory, and are not in a position to make a definite statement. But ten stars were taken, extending over about $1\frac{1}{2}^h$ R.A., and between −12° and +12° decl. These were reduced first by the machine, and secondly by Stone's tables. The greatest discordances were $0^s{\cdot}002$ in R.A., and $0''{\cdot}03$ in δ, and the machine reductions occupied only about half the time of the tabular.

I do not think the machine could be recommended for reducing in R.A. stars of high δ, unless the same error in arc be allowed for circumpolars as for stars near the equator, for the sum of two quantities $[h \sin (H+a)$ and $g \sin (G+a) \sin \delta]$ has to be multiplied by the sec. δ. It ought to reduce any star in NPD, no matter what its δ might be.

But I think the above difficulty might be overcome with a little tabulating and a modification of the reduction formulæ. Let us suppose two stars of the same R.A., but differing in δ. Call the decs. δ_1 and δ_2. Then the *difference* between the reductions in R.A. for those stars on the same date is

$$g \sin (G+a) (\tan \delta_1 - \tan \delta_2) + h \sin (H-a) (\sec \delta_1 - \sec \delta_2).$$

Suppose now that reductions were calculated for every tenth day for decs. 20°, 40°, and 60°, and tabulated for each hour of R.A. The reduction in R.A. for a star of, say, 68° δ would be effected as follows :—

First obtain reduction of a star of same R.A. and 60° δ by interpolation from tables. Then, with the machine, extract g sin $(G+a)$ and multiply this by (tan 68° − tan 60°) = 0·743 = natural sine of 47° 59′. Similarly h sin $(H+a)$ (sec 68° - sec 60°) would be obtained, and the sum of these two quantities added to the reduction for 60° (obtained from the tables).

If this method be adopted, it will be advisable to figure the natural sines round the rim of A, and the only quantities required from the logarithm tables will be the tan δ and sec δ of each star.

Note on Mr. Cooke's Paper. By Professor H. H. Turner, M.A., B.Sc.

Just a year ago Mr. Cooke drew attention * to a method of simplifying the calculation of star-corrections in N.P.D., and I followed his paper by an account of some mechanical methods which I had been considering. An apparatus has since been constructed on the plan described in *Monthly Notices* liv. p. 367 by Messrs. Troughton and Simms, and used with success at the Royal Observatory, Greenwich.

Mr. Cooke's present paper, which I received from Sir Charles Todd a few days ago, suggests one or two improvements in this plan, the importance of which I am glad to be the first to recognise. His use of the cross reticule instead of an extra sliding piece is an obvious convenience. But much more important is his remark that it is not necessary to figure the hours, but the minutes only. This reduces the necessary size of the machine to one quarter ; or, in other words, makes it possible to have a scale twice as large as before.

I may perhaps add, in my turn, to his suggestions as follows :—

(1) It is now not necessary to have two pivoted parts of the machine, as he suggests. The arc B may be clamped to the table if only we have a pointer P which may be attached to the revolving ruler in an arbitrary manner. Thus, suppose we wish to find g cos $(G + a)$, and that $G = 22^h\ 32^m$. Set the ruler to $0^h\ 28^m$, and make the point P fall on the zero line at the distance g. Then figure the hours 3, 4, &c., instead of 0^h, 1^h, &c. Hence

* *Monthly Notices* vol. liv. p. 358.